Zinc Anodes to Control Bridge Deck Deterioration

Physical Research Report No. 69



State of Illinois DEPARTMENT OF TRANSPORTATION Division of Highways Bureau of Materials and Physical Research

- IMPLEMENTATION PACKAGE -

Illinois Modification of BPR-Type Roadometer

Ву

E. J. Kubiak

Engineer of Instrumentation Development

82 ml 2 - 67

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
to inspect the		
FHWA-IL-PR-69		
4. Title and Subtitle		5. Report Date
		December, 1977
Zinc Anodes to Control Br	idge Deck Deterioration	6. Performing Organization Code
(Project IHD-20)		8. Performing Organization Report No.
7. Author(s)		Physical Research Report No. 69
J. L. Saner		IO. Work Unit No.
9. Performing Organization Name and Addre	· · · · · · · · · · · · · · · · · · ·	
Illinois Department of Tr. Bureau of Materials and P	11. Contract or Grant No. IHD-20	
126 East Ash Street Springfield, Illinois 62706		13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address		1
Illinois Department of Transportation		Final Report
Bureau of Materials and Physical Research		Nov. 1973 - Dec. 1977
126 East Ash Street	14. Sponsoring Agency Code	
Springfield, Illinois 62		
15. Supplementary Notes		

Study conducted in cooperation with U. S. Department of Transportation, Federal Highway Administration

16. Abstract

This report described a field investigation of the use of sacrificial zinc ribbon anodes to cathodically protect the reinforcing steel in a bridge deck, thus controlling spalling.

After 3 years the zinc anodes were found to be capable of protecting only a three inch (7.62 cm) wide strip 'each side of the anodes.

•		
17. Key Words		18. Distribution Statement
	+	No restrictions. This document
		is available to the public through
Cathodic protection, sacrificial		the National Technical Information
zinc apodes, bridge deck		Service, Springfield, Virginia 22161
19. Security Classif. (of this report)	20. Security Cl	lassif. (of this page) 21. No. of Pages 22. Price
		22
unclassified unclassi		fied ZZ

- IMPLEMENTATION PACKAGE - Illinois Modification of BPR-Type Roadometer

INTRODUCTION

Of all the characteristics of a pavement, riding quality has the greatest influence on the highway user in his judgment of service being provided by a pavement. Public acceptance of a pavement from the standpoint of riding comfort is a major concern of the highway engineer.

BPR-Type Road Roughness Indicators (Roadometers) have been used for several years to measure the as-constructed riding quality of newly constructed pavement surfaces in Illinois. This type of device has been proven to be very dependable and easy to operate, and a high degree of confidence is associated with the results obtained on pavement segments 1/2 mile or more in length. However, two specific limitations of the Illinois BPR-Type Roadometers are that the systems are not capable of providing reliable results for pavement segments much shorter than 1/4 to 1/2 mile in length, and that the operating test speed of the equipment is limited to 20 mph.

These limitations are of significant importance for several reasons. First, the roadometer ideally should be capable of testing at speeds close to the normal flow of traffic for obvious safety reasons. Second, by increasing the test speed, the volume of tests that could be made each season would be increased. Third, the roadometer would be a much-improved research and test tool if the device were capable of measuring short segments of pavement with a high degree of confidence in the accuracy of the results.

The primary purpose of this report is to provide detailed information on the modifications that were made of the type that will permit others to make the same or similar modifications to their equipment.

DESCRIPTION OF MODIFICATIONS

In an attempt to alleviate the above-mentioned restrictions, new electronic sensing devices were constructed for use in conjunction with the basic BPR-Type Roadometer to permit more precise measurements of vertical displacement and horizontal distance. Throughout the modification development, it was the goal that the new device would be capable of measuring segments of pavement as short as 100 feet with the same degree of accuracy and repeatability as the present device in measuring a one-mile segment, and that it would be capable of testing at speeds at least up to 45 mph.

A new integrator was constructed in which a commercially available unidirectional photoelectric encoder was used to replace the mechanical double-acting ball clutch and the 6-lobe cam. In the new integrator, a plastic disk with 600 small windows is attached to the integrator shaft. The windows are arranged similar to the spokes on a wheel. A small light source is focused on the disk, and as the disk rotates the light in interrupted. On the opposite side of the light source is a photocell which picks up the interruptions and generates electrical pulses. One hundred pulses are generated for each inch of cable movement. The new integrator generates a pulse for each 0.01 inch of vertical displacement as compared to one pulse per inch for the original mechanical integrator.

The frequency response of the new integrator is in excess of any operating rate needed during field tests regardless of the test speed. The encoder used was rated at 30,000 counts/sec. This rating is more than 40 times greater than would be needed to test a pavement with an RI of 360 in./mi roughness at a test speed of 70 mph.

The new integrator is attached near the top of the rear member of the "A" frame supporting device of the roadometer. A steel cable rotates the integrator shaft in the same manner as the original integrator.

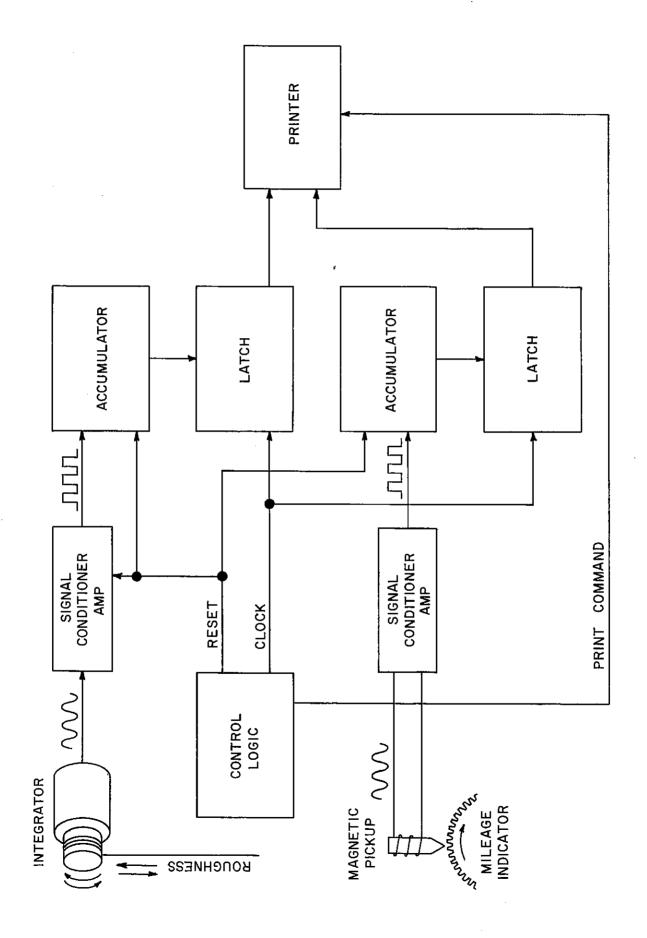
Horizontal distance accumulation was modified so that one pulse would be generated for approximately one inch of travel. An 84-tooth gear was attached to the hub of the test tire, and a proximity switch (magnetic switch) was positioned above the gear. One electrical pulse is produced every time a gear tooth passes under the switch. Laboratory tests indicate that the proximity switch can operate in excess of 1400 counts per second which, theoretically, would be sufficient to allow roadometer testing at speeds of more than 80 mph.

The count per inch of travel results in a sample length of considerably greater resolution than the original distance accumulation which recorded one count per wheel revolution, or one count per approximately 7 ft. Also, one count per inch of travel far exceeds the shortest sample length which will be needed in the foreseeable future.

The 84-tooth gear was selected for use because the ratio of inches of tire circumference versus number of gear teeth was nearly one in. per one tooth, and the gear was readily available.

A functional drawing of the modified roadometer is shown in Figure 1. Two input transducers are shown which include the vertical displacement transducer (integrator) and the horizontal distance transducer (mileage indicator). Both transducers produce crude sine waves which are fed into signal-conditioning circuits.

The signal-conditioning circuits reshape the crude sine-wave inputs into square waves. The resultant square-wave voltages are fed into the accumulators. The signal-conditioning circuit for the vertical displacement transducer also



Functional Drawing Of The Roadometer Recording System. Figure 1.

halves the frequency of the incoming signal. The halving function is needed because the integrator shaft rotates back and forth, which doubles the displacement input.

Information stored in the accumulators is fed through latching circuits and a print command into the mechanical digital printer. The latching circuits and print command circuit are included to compensate for the differences between the operating speeds of the accumulators (10 to 20 micro-seconds) and the mechanical digital printer (750,000 micro-seconds per printout).

The digital printout feature was incorporated in the modified system to eliminate the need for the operator to copy field data during the field test operations. The printer can be operated automatically or manually. Functional coding is also included and a letter of the alphabet between A and I is printed each time the printer is activated. This function can be used to identify pavement features such as patches, intersections, bridges, etc.

The instrument console and printer are presently mounted on the tow truck floor between the driver and the operator, and can be activated by either person. The package is shock-mounted to the floor of the tow truck. Further consideration is being given to the possibility of densifying the instrument console so that it can be mounted on the dash or possibly hand carried by the operator.

The entire system is operated by the 12-volt D.C. power supply of the towing vehicle.

A minor modification includes the use of commercially available ball joint rod ends on the damper units instead of the ball and socket joints included on the original equipment. The new rod ends are designed and constructed so that elongation or compression of the body head does not bind or interfere with ball movement, which is an advantage not associated with the original ball and socket joints. This modification overcame the problems of variation in damping caused by wear and improper adjustment of the ball and socket joints. A final advantage associated with this modification is that the purchase price of the ball joint rod ends is considerably less than the in-house construction cost of the ball and socket joints.

Upon completion of the modifications, the new Roadometer was subjected to a field test program to provide a measure of its capability relative to meeting its intended use and to compare its operation with that of the original device relative to reliability, repeatability, and accuracy. The results showed that the modified system can be operated at test speeds up to 50 mph, and strongly suggested that the limiting speed may be in excess of 60 mph, that it is capable of measuring pavement segments as short as 100 feet with sufficient accuracy to obtain RI values that are meaningful and usable, and measurements obtained at 30, 40, and 50 mph correlated well with those obtained at 20 mph. testing indicated a need for an additional modification to permit automatic activation and deactivation of the recording equipment at the precise beginning and ending of a pavement being tested to eliminate operator error in manually starting and stopping the recording device for further improvement in the accuracy of results from tests of short segments of pavement and for more precise calibration and correlation of the equipment for different testing speeds. Work in this area is now in progress.

DETAILS OF MODIFICATIONS

In the preceding section, six separate items were discussed. These items were:

- (1) the modified integrator.
- (2) The horizontal distance pickup.

- (3) The signal-conditioning circuits.
- (4) The digital printout.
- (5) The instrument console.
- (6) The ball-joint rod ends.

Following is a description of each of the above items and information on the various manufacturers' products which were used. An overall schematic diagram of the modified system is shown in Figure 2.

The Modified Integrator: The system's integrator, which accumulates vertical displacement, was fabricated in house. The encoder wheel and pickup were purchased from "Disc Instruments, Inc., 2701 South Halladay Street, Santa Ana, California, 92705." It is a model No. 800 with 600 pulses per shaft rotation. A more detailed description is published by the manufacturer in their bulletin No. 488. Shop drawings of the fabricated parts of the integrator are shown in Figures 3-A through 3-D.

It has come to our attention that the encoder can now be obtained preassembled from "Disc Instruments, Inc." A second source for the complete unit is Dynapar Corp., Gurnee, Illinois 60031.

Figure 4 is a photograph of this integrator.

The Horizontal Distance Pickup: The magnetic pickup unit was purchased from the "Electro Corp., 1845 57th Street, Sarasota, Florida 23580," Part No. 3022. This pickup has only one adjustment which requires some attention. The low frequency cutoff is in the most part controlled by the "gap" or distance between the pickup and the gear teeth. We have adjusted ours to operate from a speed of two miles per hour or faster. The gear used was manufactured by the Boston Gear Works, Quincy, Mass., Part No. GB-84, 16 pitch. The mounted pickup is shown in Figure 5.

The Signal Condition Circuits: The purpose of these circuits is to transform the output of the encoder and distance pickup to wave shapes which are acceptable

amount of polarization decay is to be adjusted by the immediate or instantaneous shift. For the deck in this study instantaneous shift was found to be very small or nothing and because of this it was ignored in adjusting the following data.

On March 14, 1975 potentials were measured with the system on. On April 28, 1975, after 45 days off, potential measurements were made again at the same locations measured on 3/14/75. The decay for groups (0", 6" [15.24 cm], and 12" [30.48 cm]) were averaged and plotted on Figure 7. As can be seen from this Figure the minimum decay of 100 mV was achieved only 3 inches (7.62 cm) from the anode. It is interesting to note that both the 100 mV decay and the 100 mV shift discussed in the previous section of this report occur at 3 inches (7.62 cm) from the anode. It is believed that 100 mV shift is sufficient to control corrosion if a method can be devised to adjust the data for "nonstatic" potentials. It is also believed that a shift of something less than 100 mV will adequately control deck spalling. The minimum shift which will control spalling needs to be empirically established.

Minimum - 850 mV. Another criterian accepted by NACE and the one most widely used, is the establishment of a minimum - 850 mV potential between the Cu/Cu SO₄ half cell and the steel. Figures 8, 9, & 10 depict the distribution of voltage potential from on to off for the 0-, 6-, (15.24 cm) & 12-inch (30.48 cm) distances from the anodes. From these figures the actual potentials achieved can be determined, and it can readily be seen that no where near the - 850 mV criteria was achieved. It is this author's opinion that the - 850 mV criteria is not applicable to bridge decks for economic reasons. In other words, achieving - 850 mV is not necessary on bridge decks if protection can be accomplished with substantially less.

Achieving - 850 mV would require over-designing the cathodic protection system.

Figure 3-A. Bearing And End Plate.

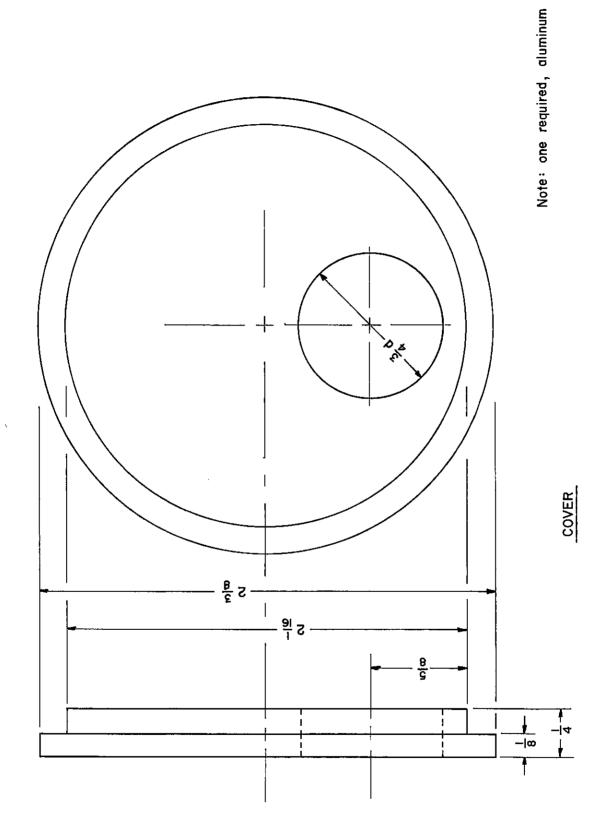


Figure 3-B. Cover For Integrator Case.

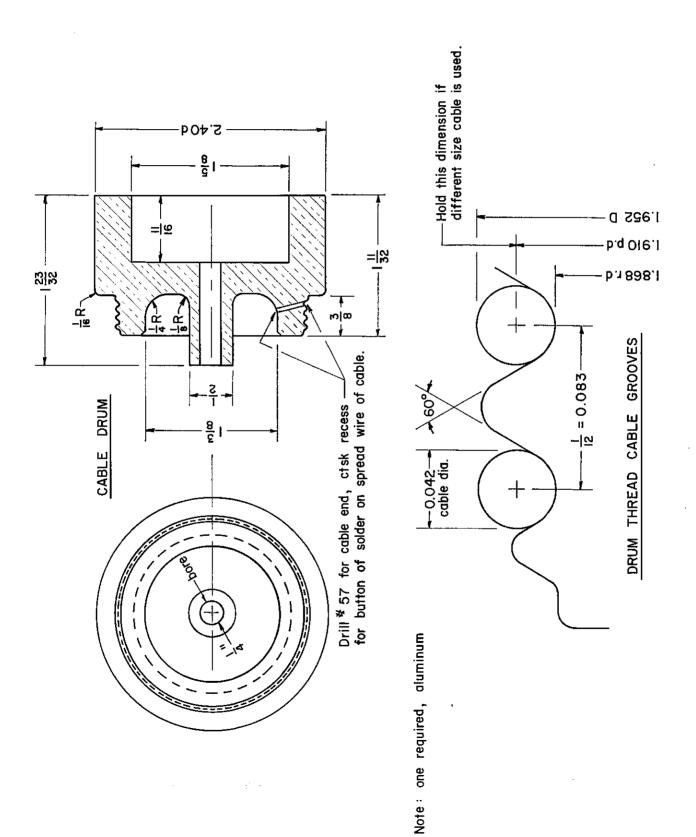
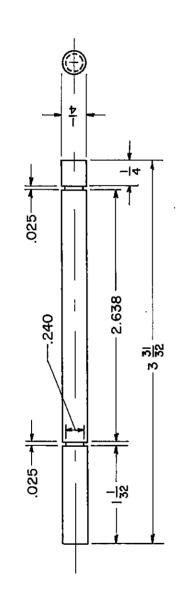


Figure 3-C. Cable Drum.



Note: Shaft - one required, stainless steel Case - one required, aluminum

SHAFT

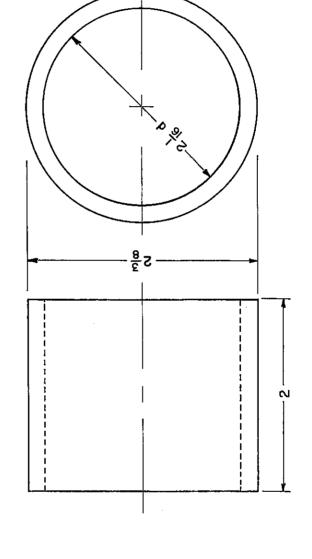


Figure 3-D. Integrator Shaft And Case.

CASE

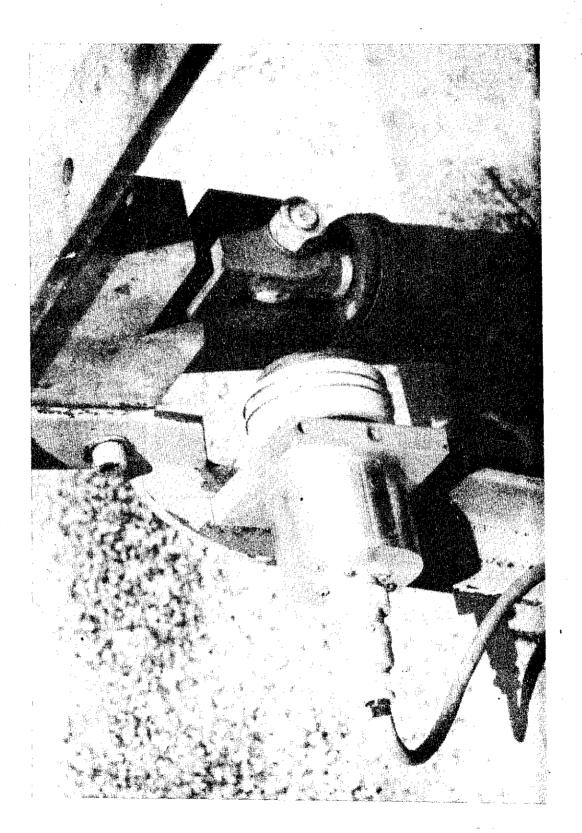


Figure 4., New electronic integrator and new rod end on the damper unit

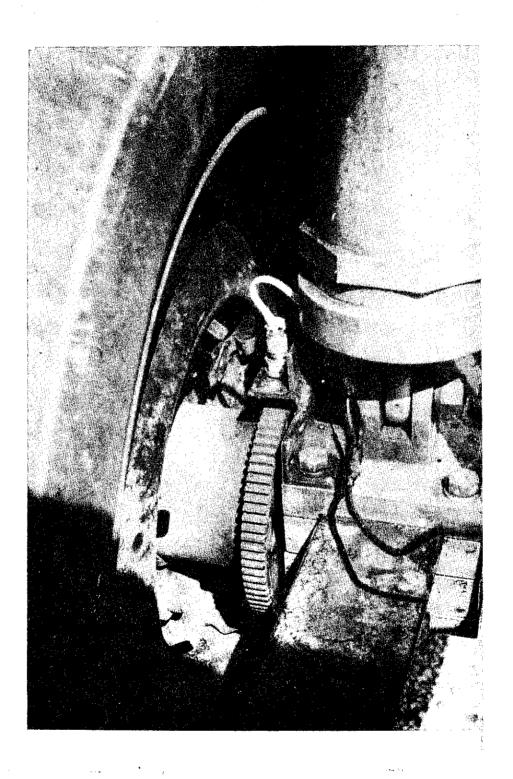


Figure 5. Horizontal distance measuring device

to the TTL logic. The attached schematic drawing shows these circuits. The encoder circuit consists of an IL-5 optical isolator, a 7413 Schmitt trigger, and a 7473 flip-flop. The distance pickup circuit consists of a 741 op-amp and Schmitt trigger.

The Digital Printout: The printer was manufactured by "Practical Automation, Inc., Trap Falls Road, Shelton, Connecticut, 06484." It is model B5-128. This particular model is capable of operating off the vehicle's 12-volt battery, and is TTL compatible.

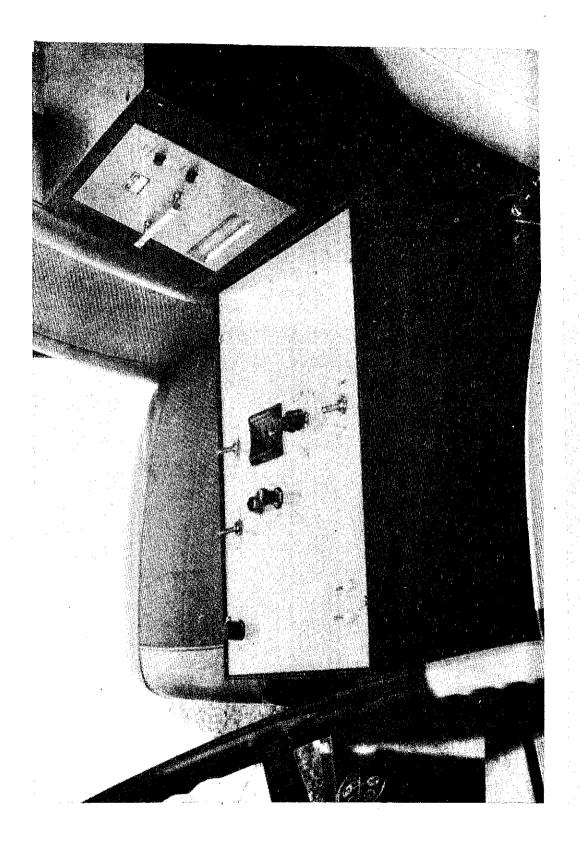
The printer requires 12VDC + 10%-0 and 5VDC. The 5VDC \pm 0.1% was obtained by dropping the 12VDC to 5VDC by using an LM309 regulator. This regulator is not shown on the schematic, but is commercially available.

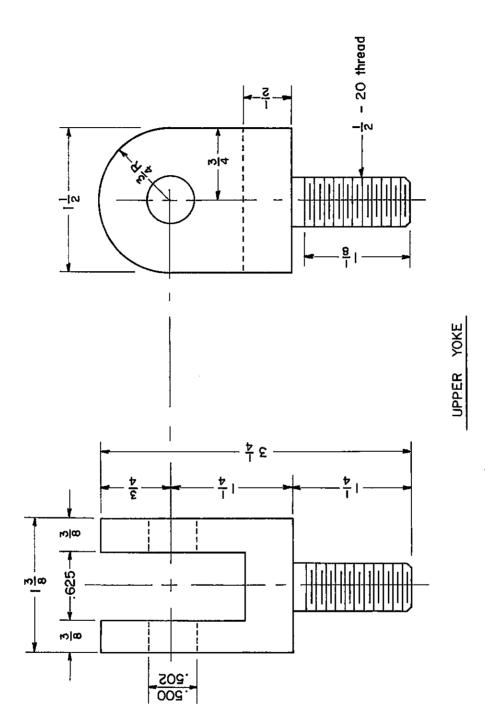
The Instrument Console: A suitable console could not be found so the console was locally fabricated. The console is shock-mounted and grounded to the vehicle's body. A photograph of the console and printer is shown in Figure 6.

The Ball-Joint Rod Ends: The rod ends used were manufactured by Seal Master Bearings, a division of Stephens-Adason Mfg. Co., Aurora, Illinois, and are part numbers FR-8 and FRE-8. Special yokes were fabricated to accommodate the rod ends. These yokes are shown in Figures 7-A and 7-B. The rod ends were modified to the shape and dimensions shown in Figure 8. Figures 4 and 5 show the rod ends and yokes.

Reference: "Modification of the BPR-Type Roadometer" by J. E. LaCroix and E. J. Kubiak, Illinois Department of Transportation, Division of Highways, Physical Research Report No. 63.

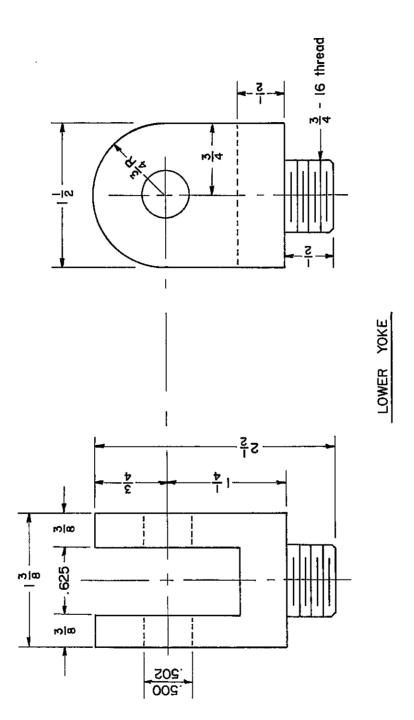






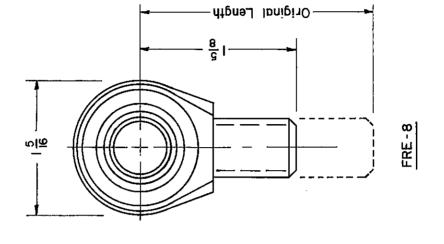
Note: 2 required, cold rolled steel

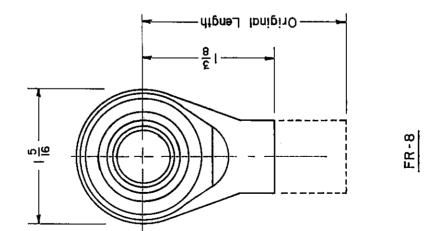
Figure 7 - A. Upper Yoke For Ball - Joint Rod End.



Note: 2 required, cold rolled steel

Figure 7 - B. Lower Yoke For Ball - Joint Rod End.





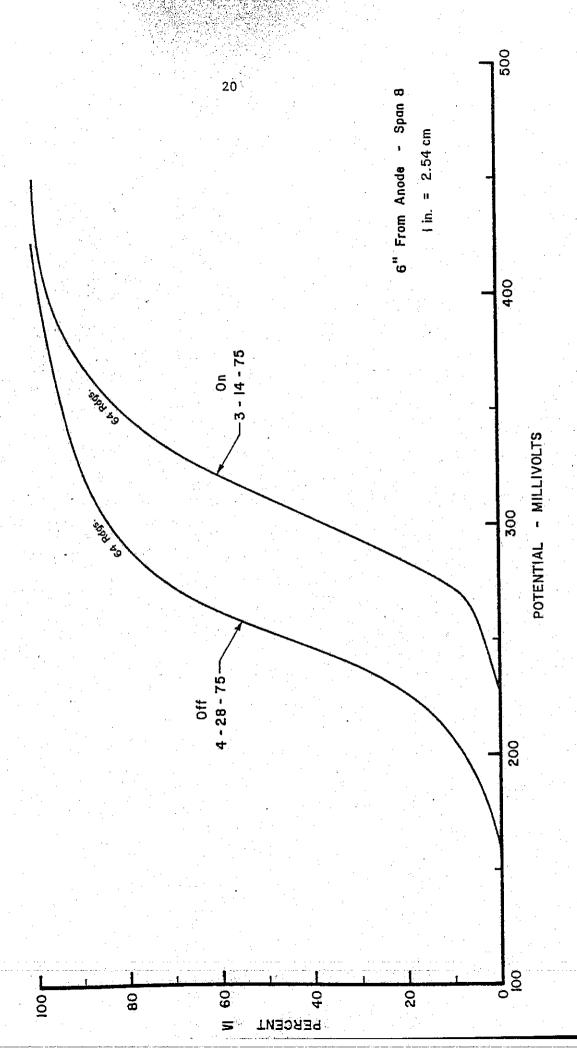


Figure 9. Distribution Of Steel Potentials

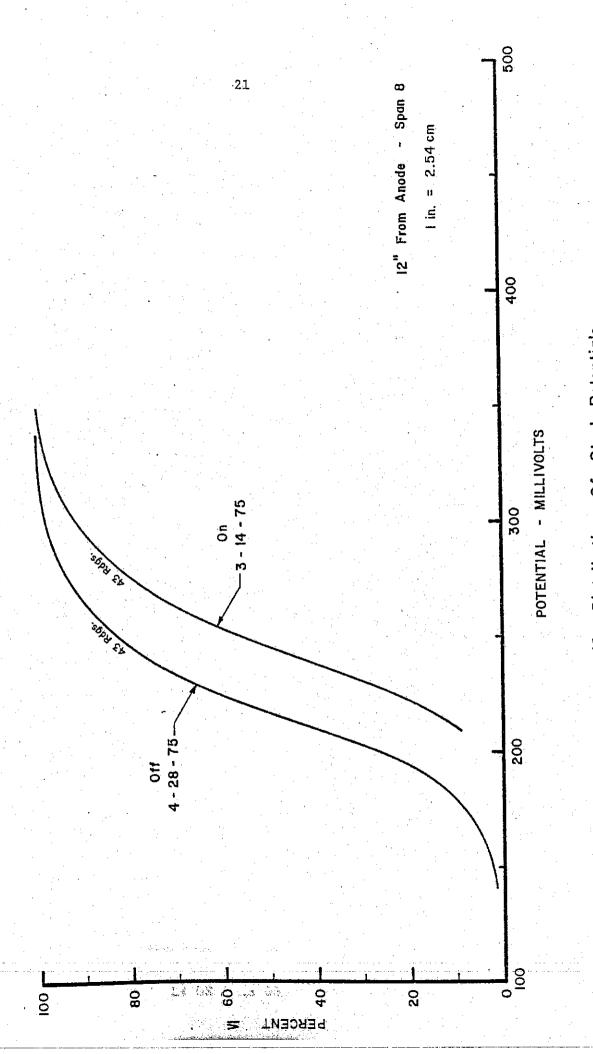


Figure 10. Distribution Of Steel Potentials

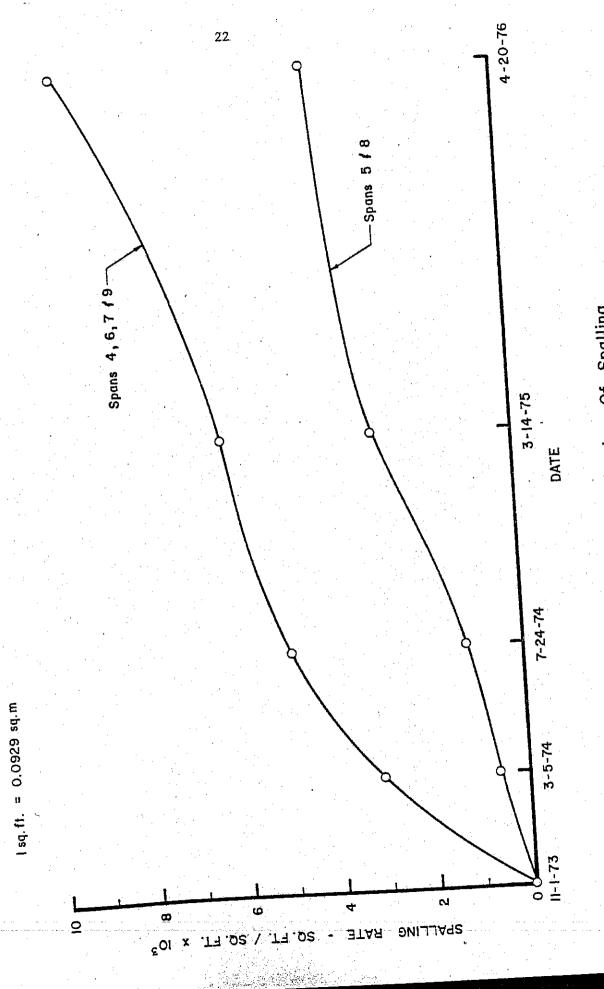


Figure 11. Progression Of Spalling